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ABSTRACT

Reducing the costs of teaching by television through slow-scan methods is discussed. Conventional television is costly to use, largely because the wide-band communications circuits required are in limited supply. One technical answer is bandwidth compression to fit an image into less spectrum space. A simpler and far less costly answer is to transmit still images only, through what has been called slow-scan television. Transmission rate is reduced and bandwidth can be reduced, with a corresponding increase in the number of video communications channels available. Slow-scan television or "still picture" television is available from several manufacturers, but it is still a very small industry, with most efforts concentrated on equipment designed to operate within the existing telephone network. Satellite experiments with still videos date back to the 1960s, and a variety of techniques can be used for transmission. Several projects have used still video transmission. The most significant project has been a news program service by United Press and a satellite channel focusing on women's issues. The approach has been used in medical education, in other educational endeavors, and by the government for a variety of uses. Although the effectiveness of still video image has been demonstrated, it has not found widescale adoption. (SLD)

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USE OF SLOW-SCAN TELEVISION SYSTEMS IN TELEMEDICINE,
DISTANCE EDUCATION, GOVERNMENT, AND INDUSTRIAL APPLICATIONS

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COLORADO VIDEO, INC.

Presented at the United Nations International Seminar on the
"Development and Applications of Satellite Communication Systems"

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USE OF SLOW-SCAN TELEVISION SYSTEMS IN TELEMEDICINE, DISTANCE
EDUCATION, GOVERNMENT, AND INDUSTRIAL APPLICATIONS

Glen Southworth - Colorado Video, Inc.

Teaching by television in the United States essentially began in the early 1950's. The Ford foundation and various other agencies provided millions of dollars for experiments in this new and novel form of communication. Over the next 30 years it was discovered that it was indeed possible to instruct students at a distance by this form of electronic image transmission, and since then television has been used to provide a wide range of instruction from advanced engineering courses to music classes for first and second graders.

At present, nearly every school of higher education in the United States has a television establishment of some nature, and over 400 educational TV stations are in operation. In addition to broadcasting, many institutions operate closed circuit systems on campus, use point-to-point microwave, fiber optics, low power transmitters, or video tape recordings in order to further extend instructional capability. The National Technological University, based in Colorado, uses satellite facilities to transmit engineering courses to a nationwide audience, and NUTN in Oklahoma also provides a wide range of satellite delivered educational material. Both organizations foresee rapidly growing audiences, and other schools are looking forward to the use of satellites. In addition, American industry is becoming a major user of instruction by satellite, with corporations providing training to employees and customers by this means.

In spite of all of this activity a skeptical observer might question whether television based instruction, as it is currently practiced, really serves more than a relatively small fraction of the population. A basic fact is that conventional television is costly! Not necessarily from the standpoint of camera, monitors, or other hardware, but because the wide band communications circuits required are in limited supply. To point out the disparity between present practices and potential useage let me provide two examples.

Arapahoe Community College is a two year school of modest size in Denver, Colorado. It has an enrollment of 6,700 students and offers 27 courses in general studies as well as 47 courses in occupational subjects. The transfer of this school's total basic instruction to television format is an interesting subject for speculation. Would it require the use of 74 transponders, nearly the full capacity of three satellites? More? Less? What amount of spectrum space would be required to duplicate the teaching capabilities of a major university such as Harvard, Massachusetts Institute of Technology, or the University of Illinois?

Video teleconferencing, in the form of person-to-person or group-to-group visual communications, has received an increasing amount of attention in the last ten years. Again, the problem of limited wide band communications capacity provides a serious restriction to what might otherwise become a high degree of useage.

A town such as Boulder, Colorado has a population of approximately 85,000 people, a major university, a division of the National Bureau of Standards, and is the home of a number of high technology manufacturing and research organizations. Assuming serious use of video communications, peak demand in this one community might easily exceed 200 channels, or the equivalent of eight older generation satellites.

The technical answer is, of course, bandwidth compression in order to fit an acceptable video image into substantially less spectrum space than four to six megaHertz. Research in this area has been carried on since the 1950's and has involved efforts on the part of universities, industry, and various government agencies such as NASA. The rapid growth of digital technology has made feasible the implementation of complex, high speed computation, which in turn has allowed some very impressive reductions in the data rates required for video signal transmission. For example, Compression Laboratories, a U. S. firm, manufactures equipment that transmits quite acceptable video images at a serial bit rate of only 375,000 bits per second.

Another technical approach which is far simpler and less costly is to transmit still images only. Again, work in this area seems to date back to the early 1950's with the International Telephone and Telegraph company being one of the earliest organizations to manufacture commercial hardware.

The rationale for "still picture" television, or Slow-scan TV as it was earlier called, is simple. In order to create an acceptable semblance of motion conventional television transmits 25 or 30 highly redundant images per second. If the transmission rate is reduced to ten seconds per picture there will, of course, be no motion in the display, but bandwidth can be reduced by a factor of 250 or 300 (depending upon where you live) and a roughly corresponding increase in the number of video communications channels made available. Further bandwidth economies can be obtained by lengthening transmission times or by reducing the resolution of the transmitted image.

An additional advantage of Still Picture transmission is that it may be adapted to virtually any communications medium from that of basic voice grade circuits, such as the dial-up telephone system, to high speed digital data systems. Either analog or digital transmission may be employed, and still images may also be intermixed with conventional television transmissions in several different ways.

Slow-scan television hardware is available from a number of manufacturers throughout the world, but is still a very small industry with most vendors preferring to concentrate their efforts on equipment designed to operate with the existing telephone network. A very widely used technical approach is to use standard television cameras and monitors for image acquisition and display as these are widely available and relatively inexpensive. For transmission purposes a scan-converter using solid state components is typically used, first accepting the wide band video input from the TV camera, storing a single field or frame in memory, then transmitting it at a low rate. In a receiving mode, the scan converter accepts data at a low rate and feeds it into a memory which is then read out at high speed to recreate an image on a television monitor.

Because scan conversion is an essential part of the above described process, it is a simple matter to change the format in the final picture. In many instances a lower resolution image is generated in order to allow faster transmission, fewer memory components, or more programs in a given channel bandwidth. Conversion from a conventional video input source of 480 x 512 pixels to 240 x 256 pixels in the final display is relatively common in the United States, and is used in many classroom situations as it provides a reasonable match to the visual acuity of students who may sit fifteen feet or more away from the television screen.

High resolution still picture systems are also practical, though appreciably more costly. Either conventional TV cameras or special scanners may be used for image origination and solid state memories used at the receiving location for conversion and display. (1.) Such systems may reproduce images with resolutions of 1000 by 1000 pixels or greater, and are capable of reproducing a full page of typewritten text, but should be considered with care due to the previously mentioned limited visual acuity of the average observer. The use of high quality large screen video projectors or individual high resolution monitors are thus indicated in this situation.

Transmission of still images in color is another available option which may be very significant in some applications. Again, common practice is to use conventional television cameras for initial image acquisition. The scan conversion process then may take place in several different ways such as transmission of simultaneous or sequential red, green, and blue components, or a direct conversion of a composite encoded PAL or NTSC signal. At the receiving location a reconverted RGB signal may be displayed directly on a monitor for highest quality diagnostic use, or more typically an NTSC or PAL form of video signal is generated for display on conventional monitors or television sets. High resolution color is also now available if required.

Satellite experiments with still video date back to the 1960's, and a variety of techniques have been used for transmission purposes. Among the resources available are Single Channel Per Carrier (SCPC) operation, the use of subcarrier channels added to a conventional video signal, insertion of still image data in one or more television lines in the vertical blanking interval of a normal video signal, and the use of digital channels at the desired bit rate. An interesting variation, experimentally used by Westinghouse, was to transmit still images and compressed audio over a single wide band video channel through use of time division multiplexing.

The satellite is ideally suited for the "broadcast" transmission of information over a wide geographical area, but applications can also include simple point-to-point communications, particularly in the case of remote, hard to reach locations. Ground station equipment can range from fixed station "Teleports" to portable transmit/receive terminals that are packaged in two suitcases. Still frame video equipment is available in the form of inexpensive systems operating over voice grade circuits, to high quality color systems using studio grade cameras and computer picture storage, retrieval, and image processing.

1. Southworth, Glen R. A High Definition Still Frame Television System, SMPTE Publication, "Video Pictures of the Future," 1983, pp. 44-56.

Projects utilizing still video image transmission by satellite have included:

- Project "Prelude," an experimental teleconferencing demonstration jointly conducted by NEC, IBM, and COMSAT.
- Emergency medical services provided by the Memorial University of Newfoundland to personnel aboard off-shore oil platforms.
- Medical services, including training in procedures, to small, isolated, villages in Canada, through cooperation of the Sunny-Brook hospital in Toronto and other institutions.
- Medical training to a series of small hospitals in Appalachia, sponsored by the United States Veteran's Administration as part of experimental demonstrations using the ATS-6 satellite.
- Medical assistance to the British Antarctic expedition from the Center for Off Shore Health in Aberdeen, Scotland.
- A commercial venture in California providing high quality transmission of X-Ray images from a mobile uplink.
- Weather monitoring in Alaska to assist aircraft landing at Valdez
- Use by the University of the South Pacific for instructional and other communications using a voice grade channel on the ATS-1.
- Experimental use by oil companies from both land based and off-shore platforms for assistance in trouble shooting procedures.
- Emergency disaster tests by NASA using portable equipment.
- Engineering conferencing by U. S. aerospace companies
- Communications by U. S. Government agencies
- Transmission of continuous, 24 hour, news programming to cable systems throughout the United States.
- Origination of a specialized 24 hour informational program service designed for the women's audience.

The last two items deserve special mention, as they probably represent the most significant use of still picture transmission by satellite. The first, a program service created by United Press, International, provided continuously updated national and international news in the form of still images and simultaneous voice commentary. Programming was originated and uplinked near Atlanta, Georgia, and was transmitted by using two subcarrier channels of transponder #6 of SATCOM II. The main portion of the transponder carried "real-time" programs from what is now WTBS, a "Super-station" reaching millions of viewers via cable.

The program service was called "UPI Newstime" and obtained most of its visual program material from UPI facsimile transmissions, as well as from a 35 mm slide library also provided by UPI. A ten kiloHertz channel was used for picture transmission and allowed a new monochrome image to be transmitted every eight seconds. Associated audio was carried over a five kiloHertz channel, providing good voice quality as well as being adequate for the limited amount of music used.

"Newstime" programs were first prepared on conventional video-tape equipment which then continuously played back a 15 minute segment of news, with audio being transmitted directly and the video portion being reduced in bandwidth to approximately eight kiloHertz by means of a simple, high quality, scan converter. A dot-interlace format was used in order to achieve superior subjective image quality similar to the techniques used in printing processes. Note that though the system had the capability of updating pictures every eight seconds it was found that operating this rapidly was annoying to the average viewer, and appropriate delay in the introduction of new visual information was an important factor in audience acceptance.

Receiving locations for the UPI Newstime service were typically cable television "head ends," where satellite downlink equipment was used to receive conventional TV program services. Two subcarrier demodulators provided audio and narrow bandwidth video signals, with the latter being re-converted to 525 line U. S. TV standards before retransmission to cable viewing homes. In this manner a relatively inexpensive installation could provide a continuous news service to thousands of individuals in the cable system's service area. Pictures appeared on the television screen growing from left to right over an eight second period, thus giving a sensation of movement.

UPI Newstime reached approximately one million homes, and appeared to achieve remarkably good viewer acceptance. This was born out by a full scale audience survey by the A. C. Nielson company early in 1980. To a degree this is probably due to the fact that no similar news offering was available at that time, nevertheless the success of this form of video news delivery led to the creation of a second program service using still picture transmission, this time in full color.

The "Woman's Channel" was initiated by Southern Satellite Systems, a company based in Tulsa, Oklahoma. Two hours of new programs were produced daily, video taped, and the tapes flown to an uplink site in Georgia for conversion to the still image format and subsequent transmission by satellite subcarrier. As a 24 hour service, tapes were replayed 12 times a day, while on weekends the preceding ten hours of material was rebroadcast.

As with UPI Newstime, only a small staff was required to handle all of the operations of the Women's Channel, and much of the material used was obtained through cooperation with several well known women's magazines such as the "Family Circle." Although no formal audience study was made, the service reached approximately one half million homes on a 24 hour a day basis, and the same still picture programming reached nearly three million additional homes for two hours daily on a separate, full bandwidth, program service.

In general, still picture informational or instructional programs are easy to prepare and are low in cost. Although images of the presenter and participants are desirable to establish a sense of rapport, the essential factor is meaningful graphics. These might include images from slides, photographs, drawings, schematics, blueprints, models, anatomical views, microscope slides, or any of a variety of images that can usefully illustrate voice commentary. A very important point, however, audio must be clear and easy to understand no matter how good the pictures.

Still picture origination hardware can be simple and inexpensive, consisting of as little as an industrial grade TV camera, monitor, and a scan converter connected to the communications link. In many instances the individual presenting a program will also operate both video and audio equipment, and in this case it is useful to have graphic information pre-prepared in a suitable TV format in order to minimize interruption while the speaker repositions and focuses the camera.

The use of two or more cameras, a slide projector, and other video devices can substantially improve the smoothness of a presentation. In many instances it may also be desirable to have a second person operate the video equipment, thus leaving the presenter free to concentrate on the material at hand. Programs may also be prepared in advance in a variety of ways, with perhaps the simplest being to use a conventional video tape recorder and subsequent play back of the tape through a scan converter as was done in both the UPI Newstime and Women's channel operations. Image storage in low cost personal computers is also practical, and gives the equivalent of an "electronic slide projector," but with much greater versatility.

Receiving location equipment is also simple and straightforward, with a scan converter generating a conventional video signal from the narrow band still picture transmission. Audio and video may be reproduced separately, or combined in a small radio frequency modulator for retransmission to ordinary television sets. Again, the fact that both video and audio signals are in a conventional format means that large screen display, videotape recording, distribution by coaxial cable, and other operations are easy to accomplish. Further, by using two or more memories in the receiving scan converter it is practical to display multiple images to an audience.

To date, the majority of users of still frame video communications systems have used terrestrial communications circuits. The applications are worth noting because in many instances satellite transmission would be feasible if economics permit. In the field of education Michigan Technological University has provided instruction at various levels by transmitting narrow band still video signals over a 67 kHz subcarrier of WGGL-FM, and educational radio station in Houghton, Michigan. Simultaneous audio was carried on a second subcarrier, leaving the main channel available for normal programming. A second project in South Bend, Indiana also used FM radio station subcarriers to provide instruction to grade school and high school students. Utah State University is presently providing special courses, in color, to towns throughout Utah by using one TV line in the vertical blanking interval of conventional television programs transmitted by a commercial station in Salt Lake City Utah. The Utah project also features selective addressing of pictures, as well as placing two 26 inch color monitors in each classroom to allow two different images to be displayed simultaneously.

Voice grade telephone circuits, either dedicated or dial-up, have been widely used for instructional purposes, with virtually all systems incorporating full, two way, interactive communication. In this category Utah State University has a network of 15 locations, the University of Wisconsin formerly serviced 26 cities, and approximately 40 other schools in the United States and Canada have operations of varying size. In two cases, the University of California at Chico, and West Hartford public schools in Connecticut transmit live full motion TV programs to the classroom, and use still image video to send pictures of the students back to the teacher.

International instruction via voice grade circuits has included three medical teaching projects: The University of Ottawa in Canada and a teaching hospital in Kingston, Jamaica using full color image transmission of diagnostic quality. The Memorial University of Newfoundland, Canada, and the University of the West Indies. New York University and students in Puerto Rico. In addition, the University of Hawaii has conducted a series of still image meetings between language students in Hawaii and students in China, Hong Kong, Korea, and Japan. The University of Cincinnati has provided supplementary material to a visiting professor in China, and the Massachusetts Institute of Technology has participated in special demonstrations of video art to groups in Vienna, Austria and Zurich, Switzerland.

Instruction by means of still image video has included medicine, engineering, sociology, language, government, history, art, and telecommunications courses. Further, several institutions, such as the University of Denver and the University of Cincinnati, have conducted experimental programs in library information retrieval. A significant use of still frame video, pioneered by Dr. David Swift of the University of Hawaii, is the presentation of guest lectures by well known scientists with images and audio being transmitted to the classroom from the presenter's own office or laboratory.

A novel experiment in the combination of still frame television and satellite transmission was conducted in the fall of 1986 by Colorado Video. In this instance, authorities in the field of Tele-education used still picture television equipment to make presentations by satellite to a nationwide audience. Speakers in five different locations throughout the United States, including the island of Hawaii, employed the "dial-up" telephone network to transmit images and commentary to an uplink location in Colorado. At this point the narrow band video signals were scan-converted back to normal broadcast standards for distribution via satellite to approximately 40 viewing locations throughout the country. Total cost for the one hour and fifteen minute program was a small fraction of that which would be involved in the case of live "real-time" origination from each of the sites.

The medical profession has shown interest in still picture transmission since the 1960's. As might be expected, a major area of activity is in the remote interpretation of X-Rays and related radiological images such as Ultrasound, Infrared, Nuclear, NMR, and CAT scans. A firm based in Los Angeles, California, Professional Satellite Imaging, now has a fleet of four mobile uplinks for use in transmission of such diagnostic material from small hospitals, clinics, or private residences back to central facilities for professional readings. Telephone line transmission is also being used by as many as 500 radiologists in the United States and Canada, but generally does not have the quality or speed of satellite communications.

Medical uses of still frame television include consultation with specialists, and the ability to provide 24 hour a day diagnostic services in emergency situations. In addition to X-Rays, imagery may include observation of cuts, burns, or other trauma, and experimental use has been made in Opthamology, Dermatology, and other disciplines including psychiatry.

Emergency medical assistance has been provided to at least one major U. S. corporation, ships at sea, remotely located construction projects, oil well platforms, and small, isolated, villages. In the latter case, two way visual communications has proven valuable in minimizing mental anguish of patients that have been removed to a large city hospital for treatment, as the ability to see and hear family members may ameliorate the distress of strange and sometimes frightening surroundings.

Use of still frame video by government agencies has encompassed a wide range of applications. Without going into detail, a partial listing is as follows:

- Evaluation of quality requirements for the transmission of X-Rays
- Ship to ship and ship to shore emergency medical research
- Administrative teleconferencing
- Transmission of scientific data
- Observations of Solar phenomena
- Data remoting in varicus applications
- Transmission of radar images
- Library information retrieval
- Mine rescue operations
- Educational projects
- Emergency situation monitoring
- Weather and environmental monitoring
- Records retrieval

U. S. Government agencies have also sponsored a number of experimental projects in education and medicine.

In the commercial sector still picture video has also been widely used, primarily by major corporations such as IBM and aerospace companies such as Pratt & Whitney. Although video teleconferencing is frequently thought of as being the province of executives, in practice a series of other applications may be of substantial importance to an institution or business enterprise.

In addition to executive meetings a corporation may find still frame video useful in the following areas:

Advertising	Field service
Consultation	Information retrieval
Construction projects	Instruction
Engineering	Medical assistance
Environmental monitoring	Sales presentations

Fast, low cost, visual communications can be highly valuable in solving production line problems or providing needed expertise in many other industrial or engineering operations when even one days delay may mean costs of literally hundreds of thousands of dollars.

International video communications are practical and relatively low cost when still picture transmission is used. In an increasing number of situations the engineering and subsequent production of major products such as automobiles requires international cooperation. As an example, the Ford Motor Company has used still image communications to coordinate engineering design work in the United States, Great Britain, Germany, and Italy. General Electric has used the same technology to speed up the analysis of metalurgical samples by transmission of electron microscope images from an installation in Ohio to operations in Berlin and Tokyo.

In conclusion, regardless of the potential excellence of a given technology it must find a niche in the real world or it will be ignored. The effectiveness of still image video has been proven in many situations, but it still waits any form of wide scale adoption. Nevertheless, in the 1990's the combination of satellites and still video will have the ability to serve thousands of informational needs and millions of people throughout the world.

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